EXPERIMENTS IN REARING COLONIES OF BUMBLE-BEES (BREMIDÆ) IN ARTIFICIAL NESTS.[1]

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Introduction.

In a detailed study of the life history of the bumblebees and their inquilines and parasites, it is obviously impossible to secure all the desired information from field observations alone. Therefore, various methods of procedure are necessary and some laboratory methods must be used. An account of the methods developed for the rearing of colonies of these social bees during five years of study may seem superfluous, but in view of previous publications, the ever-increasing interest in these insects, and their economic importance, such an account has its practical as well as academic value.

Until comparatively recent times practically all of our biological knowledge concerning the activities associated with nidification were the result of the chance discovery of nests, their hasty examination, and more rarely their observation for a limited period of time. To a large extent the classical observations of Réaumur (1742), Huber (1801), Lepeletier (1836), Putnam (1864) and many others were the result of this type of study. It is but natural, then, that the information so accumulated should relate for the most part to the size of the colonies, the inquilines and parasites found in the nest when opened, the arrangement of the comb, and various other readily apparent details of the nest economy. Such a method, however, can not be depended upon when a more detailed study of the life history of the individual bees and the development of the colony of one or more species is desired. Furthermore, the fact must not be

[1] Contribution from the Entomological Laboratories of the University of Illinois, No. 106. Extract number three from a thesis presented to the Faculty of the Graduate School of the University of Illinois in May, 1923, in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

overlooked that the vast majority of the colonies discovered in their natural environments are found at a time of the year when little can be learned about many of the aspects of their life history; the starting of the colony, for example.

Hoffer (1882–1883) says on page eleven of the first part of his celebrated publication that he has never seen how the comb is started and adds that apparently neither has any other observer. In the appendix of the second part of this work, however, Hoffer tells how to his great joy he finally observed the start of the comb of *B. lapidarius.* In this latter instance the queen was under confinement and the information obtained by Hoffer concerning this phase of the development of the comb was not based on field observations. Westerlund (1898) has given us a short account of a nest in its incipient stages that he found in Finland and v. Buttel-Reepen (1903) gives a few notes on the subject furnished him by Herr Wegener. Since then Wagner (1907), Lindhard (1912), Sladen (1912), Armbruster (1914) and Plath (1923) have added to our knowledge concerning the start of the comb. Sladen and Plath give the best accounts of the start of the nest and comb thus far published. The correctness and completeness of the descriptions of these last mentioned writers are due to the fact that they did not rely upon field observations alone.

By calling attention to the disadvantages incurred by depending upon field nests and the limitations of such studies I do not mean to imply that the examination of such nests is not or has not been of importance. I merely wish to point out that by so doing one is relying to a great extent upon chance and therefore a means which does not guarantee results to one intent upon penetrating deeper into many of the details, characteristics, and mysteries of the life history of the bumblebees.

In a comparatively recent number of the BIOLOGICAL BULLETIN (1923), Mr. O. E. Plath has published an exceedingly interesting and valuable account of his "Breeding Experiments with confined *Bremus* (*Bombus*) Queens." In the introductory part of this paper Plath adequately reviews the experiments of Hoffer (1882), Lindhard (1912), Sladen (1912), and Frison (1918) of this nature, and accordingly these papers need not be reviewed again.

Construction of Artificial Nests and Technique.

My first serious experiments in confining the queens began in the spring of 1915 and were continued each spring of 1916, 1917, 1919, and 1920. As early as 1910 I tried to get queens to start nests in confinement, but the methods then employed were so poor that I will not review these futile attempts. It was not until 1917 that I succeeded in getting colonies by this method (1917). For confining the queens I used, in 1917, a small wooden box 5 inches by 7 inches by 2 inches. At one end of this box was a round opening which could be closed by the insertion of a cork. For the top I used small ruby or amber colored glass sections. During the intervals between examinations a dark cloth was wrapped about the box to exclude the light. In one corner of the box remote from the grass nest was placed a small tin, in which liquid food was supplied to the queen. In 1919 and 1920, I used boxes for confining the queens similar to those used in 1917.

Within these boxes I used various materials for making the conditions such that a queen would be induced to start a colony. Naturally, because the queens of bumblebees select the nests of field mice the first material used was the soft, day grass from such nests. Field mice always select a fine quality of grass for their nests and hence grass from such a source needs no further sorting or treatment. The nests, however, are not always easy to find and oftentimes I was hard pressed to get enough of the grass from this source for my experiments. Sladen experienced the same difficulty in getting suitable grass to use in domiciles for attracting bumblebee queens. I found that the best time and place to look for nests of this type was in early spring along a railroad right of way, after the ground had been burned over to destroy the coarser vegetation. The nests so located usually escaped destruction by the fire and were then easily perceived. The difficulty experienced at times in getting enough of these nests, led me to try to find a substitute for the finely sorted grass they contained. Cotton did not have enough "body" and the small cotton fibers became enmeshed continually with the pollen supplied the queen. The silk from milkweed pods likewise proved to be too light and fluffy, as was the case also with raw wool. In several instances I used in my boxes without alteration, except for the addition of a top covering, the nests of small birds such as those made by field sparrows.

Bumblebees always keep the brood and comb well covered, in order to exclude light, avoid temperature fluctuations, etc. When making daily observations on a colony I always found it necessary to remove the covering of the nest. When it was replaced again the workers or queen would immediately start to work and repair it. To save the bumblebees the daily repetition of repairing the top covering, I devised a square pad of four or five layers of cheese cloth, fastened these together and then placed this pad over the comb. This gave very good results. All I needed to do in order to see the contents of the nest was to lift the cheese-cloth pad, and then upon finishing my observations, replace the same. The bumblebees readily accepted this substitute for the covering of their own making and in so doing saved themselves from constantly repairing the top. As was the case with the grass top, the bumblebees plastered a thin coat or layer of wax and pollen composition on the side of the pad adjacent to the brood chamber. Later I went a step farther and coated one side of the cheese cloth pad with pure melted honeybee wax before placing it over the nest. This seemed to break the bumblebees of their habit or instinct of coating the pad with wax and pollen and hence resulted in a considerable saving to them of time and materials. The fact that the bumblebees accepted the artificial wax-lined cheese cloth pad without material change is a good indication that it fulfilled all the requirements of their instincts in this direction.

The artificial top proved to be such a decided success that I next tried to make the whole nest of cheese cloth coated on the inside with wax. I first tried lining the bottom of the box with cheese cloth, and then lining this with the melted wax. Then I placed over this a dome-shaped cover of wax-coated cheese cloth. Of course an entrance into this enclosed chamber was provided. Because of certain undesirable features I abandoned this method. Finally, I resorted to lining merely the bottom and sides of the back part of the box with four or five layers of cheese cloth and then coating this with melted wax. For the back and ceiling a single elongate pad of the right dimensions was made in the same manner as before, and then fastened to the back of the box so as to form a stationary back part and a movable covering. This could then be lifted up from the front in much the same way as one would lift the hinged lid of a box. This top pad was easily pinned to the floor in the fore part of

FIG. 1. Start of the comb of *Bremus impatiens* under controlled conditions, showing: *a*, the pollen lump containing the first egg cells and eggs; *b*, the artificial honey pot. May 2.

the box, thus enclosing a neat light-proof, wax-lined and soft-walled chamber. An entrance to this enclosure was provided by cutting out a part of the top covering, or merely by pinning to the side of the box one corner of the free end of the top.

The adoption by the bumblebee queens of this last-described artificial nest relieved me of many of my earlier worries. I no longer needed to search about in spring for the nests of field mice, for this artificial nest seemed to fulfill in every way all the requirements of the nesting instincts which are so pronounced in bumblebee queens looking for a place to adopt as their home. Further, I could purchase very cheaply all the material that I needed for making these artificial nests. As a saver of time the artificial nest was a great improvement over anything I had ever used before. The nests could be made up at any time of the year, in any number and during odd moments. Formerly, I had to look for grass suitable for my purpose in spring, the very busiest time of the year for one attempting a biological study of bumblebees.

A slight variation of this artificial nest was often used. It consisted essentially of dividing the box into two sections, by means of a wooden partition. One of these sections was then made into an artificial nest as described above and a hole made in the partition so that the bumblebees could go from one section to the other. The remaining section was then used solely as a feeding chamber.

The liquid food which must be supplied to a queen bumblebee in confinement was kept in a small tin container. In the unpartitioned box this container was placed in one corner, and in the divided type in the section adjacent to the artificial nest. The liquid food supplied to the confined queens was simply pure, strained honeybee honey diluted with water. A mixture of sugar and water is eagerly consumed by hungry queens, but does not compare for this purpose with diluted honey, principally because it is not so concentrated. Adult bumblebees as well as the larvæ feed on pollen, but sometimes in confinement the queens can not be induced to eat the honeybee pollen. To defeat this indisposition on the part of the queens to feed on pollen, I occasionally added a small amount of rye flour to the diluted honey. In this way I hoped the queens would get some of the rye flour when lapping up the honey mixture. Pollen is rich in nitrogen and when eaten by the queens in spring probably contributes to the development of the eggs, causing the queen to become "broody" and finally to seek a home. Rye flour is also rich in nitrogen, and hence might aid in bringing about the same effect. The receptacles for the liquid food should permit as little exposure of the liquid as possible. Bumblebee queens frequently climb up the sides of the box and then, reaching the top and unable to go farther, fall down again. If by chance they get sticky because of falling into the tin cover containing the honey, there is less chance of the queen starting a colony. Bumblebee queens under natural conditions keep themselves scrupulously clean. Any substance such as honey which mats

FIG. 2. Comb of *Bremus impatiens* of about two weeks development, showing: *a*, several eggs in the same cell; *b*, one of the first larval cells; *c*, groove caused by the queen brooding on the first larval cells. May 10.

down their glossy pubescence and becomes a "catch-all" for particles of dirt readily tends to make the queens dissatisfied with their quarters and as a result no comb is started. I often partially covered with stiff paper the tin lid containing the honey, leaving but a little space for the insertion of the proboscis of a bee. Almost any contrivance of this nature would suffice. If one were to confine large numbers of queens it might be profitable to devise a neater and more efficient type of feeder.

Not too much of the diluted honey should be made up at one time as it rapidly sours. I found it convenient to make up this mixture by filling a four-ounce bottle about three fifths full of honey, adding enough distilled water to nearly fill the bottle and shaking it until the honey was thoroughly diluted. A cork stopper provided with a medicine dropper was useful for drawing the diluted honey from the bottle and refilling the tin containers in the nesting boxes.

Besides liquid food, pollen is essential to a brooding queen for her personal consumption and for the proper development of her off-spring. Honeybee pollen is apparently as wholesome for bumblebees as for honeybees. One spring I tried to secure fresh pollen by removing the pollen from the corbiculæ of worker honeybees which I caught in the field. This required too much time for the quantity secured; in fact, did not produce enough for my needs. Therefore, I relied mainly upon getting the pollen from the brood frames of the honeybee. The pollen should be carefully removed, so as to avoid being mixed with foreign substances, and kept in bottles until needed. If it dries out it can be moistened again with honey. I am much indebted to Dadant and Sons, of Hamilton, Illinois, for gratuitously furnishing me with pollen in the spring of 1920.

There is no actual difference between the pollen stored by the honeybee and that of the bumblebee unless it be in the nature of the substance or fluid used to moisten the pollen in order to make it adhere to the pollen plate. This is evident from the fact that much of the pollen gathered by both bumblebees and honeybees is from the same flowers.

Before using the pollen I mixed it with enough honey to give it the consistency and plasticity of pollen freshly scraped from the legs of a foraging bee. I then placed a lump of the pollen about the size of a cherry seed in the artificial nest. This corresponded to the pollen mass collected by a queen under natural conditions when about to lay her first eggs. Besides this, I usually placed a small amount of the pollen near the liquid food as an extra source of pollen supply. That placed in the nest was intended primarily for the queen to use in building her first egg cells, but the use of this also as food did not complicate matters.

Another feature of the artificial nest was the honey pot. This was made from pure melted beeswax and modeled to imitate in every respect the honey pot first constructed by a nesting queen. I fastened this to the bottom of the nest by means of melted wax, just about one half inch distant from the pollen lump which was to serve as a future egg receptacle. Diluted honey was used for filling the honey pot. Naturally,

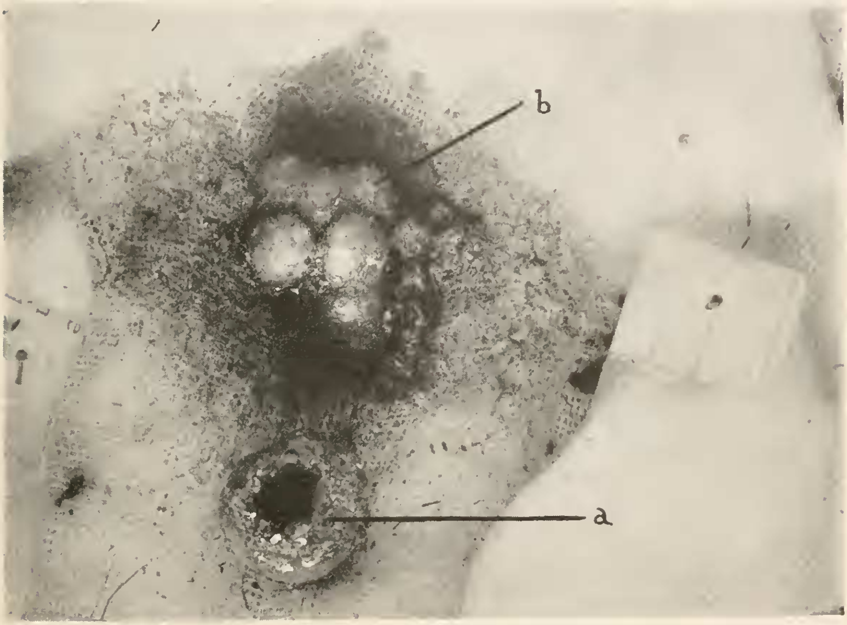

FIG. 3. Start of the comb of *Bremus vagans* in artificial nest, showing: *a*, artificial honey pot; *b*, first larval cells. June 21.

all the wax used by wild bees is produced by them, but to make conditions even more favorable I placed a few loose bits of pure beeswax near the artificial honey pot for the use of the queen if she so desired.

Considering the artificial nest as described above with all its parts, we find that it provides a queen with everything necessary for starting and eventually developing a colony. The wax-lined, cheese cloth chamber in the small wooden box in a general way corresponds to and possesses the same advantages as the nest of a field mouse. Under natural conditions after finding a suitable nesting situation the queens must gather pollen and nectar. The honey pot is constructed of pollen and wax and filled with honey, shortly after the pollen is gathered for the nucleus of the first brood mass. Occasionally I moistened a

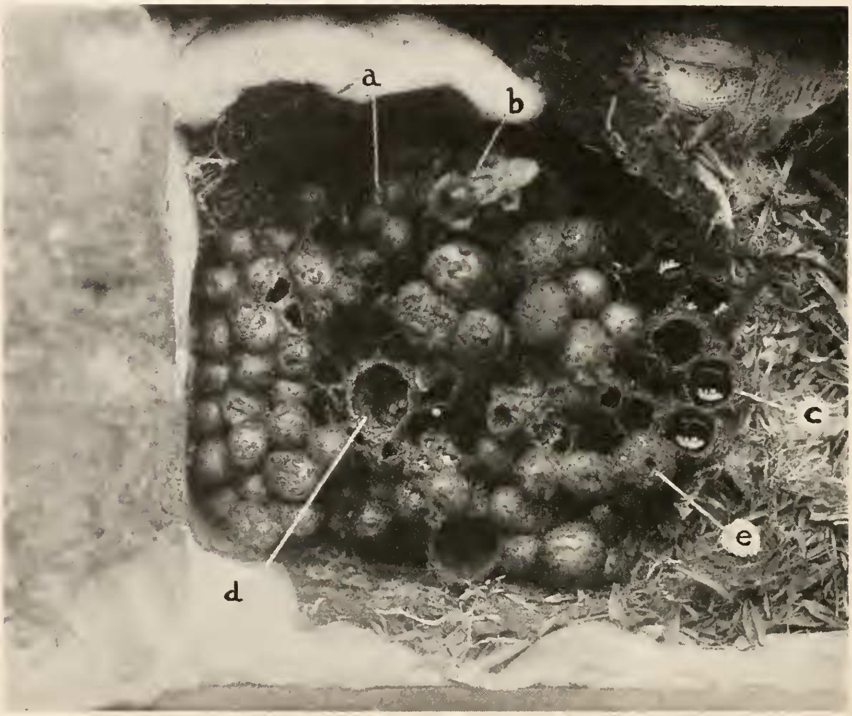

Fig. 4. Comb of *Bremus vagans*, showing: *a*, larval cells; *b*, old queen; *c*, wax-pollen pots used for the storage of honey; *d*, cocoon used for the storage of pollen; *e*, larval cell showing opening through which food is injected into the cell. September 16.

portion of the nest-lining with honey just to give it a bee-like odor. After I had placed an artificial honey pot, little bits of wax, and a small, compact mass of pollen in my artificial nest, there remained for the queen bent on laying eggs only the construction of the egg cells. Bumblebee queens under natural conditions avoid as much labor as possible. This is shown by the selection of nests of field mice, birds and other already prepared quarters. Therefore, the elimination of the work of selecting a nest, the construction of a honey pot, and the collection of nectar and pollen should prove no obstacle to inducing the queens to start colonies in confinement. In fact, my experiments prove that such provisions are the secret of success in rearing bumblebee colonies in captivity. The method involved is simply a case of substituting artificial materials and objects for those naturally found or made by the queens. In my artificial nest as described above the queen finds herself in a position or environment which would be attained naturally only after days of patient labor. The instincts associated with the early start of a colony are so fixed that the queens often proceed with work in these artificial nests that is unnecessary. As an example of this I may state that bumblebee queens under such conditions often proceed to make changes in the artificial honey pot and in some instances build a new one.

The artificial nests should be prepared in sufficient numbers before the queens are on the wing in spring, except that the pollen lump should not be placed in the nest until the queens are introduced. I have always kept a close watch on the advance of the spring season and almost the first day of the appearance of the queens caught them for my experiments. In the vicinity of Urbana, Illinois, the queens of various species appear at different times and in order to get queens of all the species commonly found in this locality, it is necessary to prolong the collecting period over an extended time. The queens were captured in an ordinary insect net and then brought alive to the laboratory in mailing tubes. On arriving at the laboratory the queens were immediately removed and placed in large glass aquarium jars. Corrugated paper was placed on the bottom of these jars to afford the queens a suitable walking surface and the top of the jar was covered with several layers of cheese cloth to prevent their escape. Food was supplied them by scattering small bits of pollen about the bottom of their prison and by placing diluted honey in a tin-container fastened in the center of the corrugated bottom. In these jars the bees found plenty of food and ample opportunity for exercise. Besides keeping the queens at all times well fed, exercise seems to be essential.

Therefore, the larger the aquarium jars the better. If the queens are kept in too close quarters, even though provided with sufficient food, they soon become lethargic and die. Queens kept in the right type of aquarium jars and well fed soon become "broody." By "broody" I mean that the physiological processes going on within the bodies of the queens cause them to display characteristic nesting instincts. This is externally expressed by the production of wax, embracement of lumps of pollen in the jar, and excited buzzing and agitated movements when disturbed. Some species respond more quickly to this treatment than do others.

As soon as the queens became broody I put them in artificial nests. Usually two queens were placed in each nest, but I conducted also ten experiments in which only one queen was placed in each nest. Needless to say, when two queens were placed in the same nest, they were usually of the same species, but in some cases I purposely placed queens of different species in the same nest-box. Before introducing two queens into the same nest it is advisable to keep them in the same aquarium jar. In this way they appear to acquire the same characteristic odor and when placed in the nest the danger of the queens fighting is somewhat lessened. Where two queens were kept in the same box, in order to be able to distinguish them apart, I marked one of them by clipping a notch in her wings. In this way it was possible to keep an accurate account of the actions of each queen. Each artificial nest was given a number when one or two queens were introduced into it and observations made and notes taken as often thereafter as possible.

Results.

In Table I. is given the results that I obtained in getting queens to start colonies in captivity. In 1915 and 1916, the methods employed were very unsatisfactory and the fact that I did not succeed in starting a single colony is not surprising. Under "Remarks" in Table I. it is to be observed that in 1915 in two of the experiments the queens at one time gave some evidence of being interested in the nest. Though these experiments are classed as failures they, nevertheless, gave me many suggestions

TABLE I.

Species.	Experiment Number.	Number of Queens and Workers.	Date Experiment Started.	Results.	Remarks.
B. impatiens	1	1 queen	April 30, 1915	Queen died May 25, 1915	Manifested slight interest in the nest
B. auricomus	2	1 queen	April 30, 1915	Queen died June 23, 1915	No interest shown in the nest
B. americanorum	3	1 queen	April 30, 1915	Queen dead May 5, 1915	No interest shown in the nest
B. impatiens	4	1 queen 3 workers	May 25, 1915	Queen dead June 1, 1915	Interest taken in the nest at first, especially by workers
B. americanorum	5	1 queen	April 23, 1915	Queen dead April 30, 1915	No interest shown in the nest
B. impatiens	6	1 queen	April 23, 1915	Queen dead May 2, 1915	No interest shown in the nest
B. impatiens	7	1 queen	May 5, 1916	Queen dead May 7, 1916	No interest shown in the nest
B. separatus	8	1 queen	May 5, 1916	Queen dead May 27, 1916	No interest shown in the nest
B. bimaculatus	9	2 queens	April 17, 1917	Colony successfully started and reared	
B. bimaculatus	10	2 queens	April 17, 1917	One queen died May 1, 1917 One queen dead May 10, 1917	Interest manifested in the nest, but no eggs or cells. First queen killed by the other queen
B. bimaculatus	11	2 queens	May 5, 1917	One queen died May 11, 1917	No interest shown in the nest
B. bimaculatus	12	2 queens	May 13, 1917	One queen stung and partially paralyzed on May 16, 1917. Other queen released later	One queen took an interest in the nest about the time the first queen was stung
B. bimaculatus	13	1 queen	April 19, 1917	Placed with Exp. 14 on April 27, 1917	Interest taken in the nest as shown by making a "cozy" pocket in the nest, but then abandoned
B. bimaculatus	14	1 queen 1 queen	April 19, 1917 April 27, 1917	Colony successfully started and reared	
B. bimaculatus	15	2 queens	April 20, 1917	One queen died May 9, 1917 One queen released on May 15, 1917	No interest shown in the nest
B. bimaculatus	16	2 queens	April 20, 1917	One queen stung and killed on April 23, 1917. One queen released on May 5, 1917	One queen interested in nest on April 23, 1917, but lost interest after that date
B. separatus	17	1 queen 1 queen	April 20, 1917 April 24, 1917	One queen dead on May 13, 1917. Other queen placed in Exp. 18 on May 18, 1917	No interest shown in nest

TABLE I.—*Continued.*

Species.	Experiment Number.	Number of Queens and Workers.	Date Experiment Started.	Results.	Remarks.
B. separatus........	18	2 queens	May 18, 1917	One queen stung and paralyzed on one side on May 24, 1917. One queen released on June 26, 1917	No interest shown in nest
B. americanorum....	19	2 queens	May 15, 1917	One queen dead on May 23, 1917. One queen released on June 3, 1917	No interest shown in nest
B. americanorum....	20	2 queens	June 21, 1917	One queen dead on July 5, 1917. One queen released on July 8, 1917	No interest shown in nest
B. bimaculatus......	21	2 queens	April 17, 1917	One queen killed on June 11, 1917 after several workers had emerged. Colony successfully reared	
B. auricomus.......	22	2 queens	May 14, 1917	One queen removed after first workers had emerged. Colony successfully reared	
B. bimaculatus......	23	1 queen	April 10, 1919	One queen removed on May 30, 1919. Colony successfully reared	
		1 queen	April 14, 1919		
B. bimaculatus......	24	2 queens	April 15, 1919	One queen removed on May 12, 1919. Colony successfully reared	
B. bimaculatus......	25	1 queen	April 16, 1919	One queen stung and killed on April 30, 1919. One removed on May 14, 1919	No interest shown in the nest
		1 queen	April 17, 1919		
B. bimaculatus......	26	2 queens	April 21, 1919	Colony successfully started. Discontinued experiment	
B. impatiens........	27	1 queen	April 21, 1919	Colony successfully started and reared	
B. impatiens........	28	1 queen	April 21, 1919	*B. impatiens* dead on May 30, 1919	No interest shown in the nest
B. auricomus.......	29	2 queens	April 25, 1919	Colony successfully started and reared	
B. separatus........	30	2 queens	May 12, 1919	One queen removed on May 15, 1919. Colony successfully started and reared	
B. separatus........	31	1 queen	May 15, 1919	Queen removed from the nest on June 13, 1919	No interest shown in the nest
B. impatiens........	32	1 queen	May 16, 1919	Colony successfully started and reared	
B. auricomus.......	33	1 queen	May 24, 1919	Queen died on June 13, 1919	No interest shown in the nest
B. impatiens........	34	1 queen	May 25, 1919	Colony started by *B. impatiens* queen adopted and successfully reared by *B. auricomus* queen	
B. bimaculatus......		1 queen	June 8, 1919		
B. auricomus.......		1 queen	June 9, 1919		
B. fervidus.........	35	2 queens	May 29, 1919	One queen removed on June 1, 1919. Other queen laid eggs, but finally deserted the nest	

TABLE I.—*Continued.*

Species.	Experiment Number.	Number of Queens and Workers.	Date Experiment Started.	Results.	Remarks.
B. separatus	36	2 queens	May 29, 1919	One queen escaped on May 31, 1919. Another queen escaped on June 16, 1919. One queen laid eggs and partially reared larvæ, but finally deserted the nest	
		1 queen	June 1, 1919		
B. separatus	37	2 queens	May 31, 1919	One queen *B. separatus* killed on June 12, 1919. Queen of *B. vagans* died on July 6, 1919 due to nematode infection	No interest shown in nest by any of the queens
B. separatus		1 queen	June 11, 1919		
B. vagans		1 queen	July 5, 1919		
B. separatus	38	2 queens	May 31, 1919		No interest shown in the nest
B. vagans	39	2 queens	May 31, 1919	One queen removed on July 5, 1919. Colony successfully started and reared	
B. fervidus	40	2 queens	June 12, 1919	*B. fervidus* queens all died at various times in latter part of June and July	*B. fervidus* queens made egg-cells on two different occasions, but each time deserted the comb
B. fervidus		1 queen	June 15, 1919		
P. laboriosus		1 queen	July 6, 1919		
B. fervidus	41	2 queens	June 12, 1919	One queen dead on June 14, 1919. Nest successfully started but not reared	
B. bimaculatus	42	2 queens	May 3, 1920	One queen removed on May 16, 1920. Colony successfully started	
B. bimaculatus	43	2 queens	May 3, 1920	One queen removed on May 16, 1920. Colony successfully started	
B. ternarius	44	2 queens	May 8, 1920	Queens escaped from nest on June 13, 1920	No interest shown in the nest before queens escaped
B. terricola	45	2 queens	May 30, 1920	One queen killed on June 4, 1920. Remaining queen constructed egg-cells but died on June 6, 1920	
B. terricola	46	2 queens	May 13, 1920	One queen removed on May 15, 1920. Colony successfully started	
B. perplexus	47	1 queen	May 30, 1920	Colony successfully started	
B. ternarius	48	2 queens	June 3, 1920	One queen removed on June 8, 1920. Colony successfully started	
B. impatiens	49	1 queen	May 30, 1920	Colony successfully started	
B. perplexus	50	1 queen	May 16, 1920	Colony successfully established	
B. centralis	51	2 queens	June 6, 1920	Large egg-cells made, but no eggs laid	
B. impatiens	52	1 queen	June 6, 1920	Colony successfully reared	
B. centralis	53	2 queens	June 9, 1920	Two large egg-cells made, but no eggs laid	
B. perplexus	54	1 queen	June 10, 1920	Colony successfully started	

for subsequent work along this line. In 1917, I secured four colonies out of fourteen experiments, or nearly twenty-nine per cent. Besides this, in four of the other fourteen experiments, the queens at one time or another gave evidence of some interest in the nest. In 1919, out of nineteen experiments the queens started colonies in thirteen of my artificial nests. This gave a successful percentage of seventy-seven plus in 1919. Two of the experiments of 1919 considered as failures should not really be so counted, for in one box one queen was killed and the other died of a nematode infection, and in the other instance both queens escaped. Out of thirteen experiments in 1920, ten must be considered as successful, or seventy-seven per cent. This same year, in two of the other three experiments considered as failures, the queens went so far as to make egg cells, and another colony might have been started if at that time it had been possible to continue these experiments longer in the spring. A survey of Table I. will show also that in 1917, 1919 and 1920 there were ten experiments in which but one queen was placed in each artificial nest. Colonies were started in seven of these ten experiments. The queens in two of the other three experiments of this nature never manifested any interest in the nest. One of the three, however, at one time took an interest in the nest, but finally abandoned it without laying eggs. All in all, I secured as good results, in proportion to the number of experiments, when one queen was used as when there were two.

Summary.

Summarizing, I find that it is possible to induce the queens of certain species of North American bumblebees to start colonies in confinement when either one or two queens are used in the experiments. Plath (1923) achieved similar results in 1922 by the confinement of a single queen assisted by "one to three workers." In 1919 and 1920, in starting colonies under controlled conditions an average success of over seventy per cent. was attained. These results are indicative that the style and make-up of the artificial nest used in 1919 and 1920, as well as the procedure followed, is the most likely to produce results of any method thus far described. Furthermore, for the first time normal

colonies of bumblebees were obtained by confining in an artificial nest a single queen unaided by introduced workers.

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